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Contents

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ABSTRACT

Three-dimensional content is becoming an important component of the World Wide Web environment. From the advent of WebGL to the present, a wide number of solutions have been developed (including libraries, middleware, and applications), encouraging the establishment of 3D data as online media of practical use. The fast development of 3D technologies and related web-based resources makes it difficult to identify and properly understand the current trends and open issues. Starting from these premises, this survey analyzes the state of the art of 3D web publishing, reviews the possibilities provided by the major current approaches, proposes a categorization of the features supported by existing solutions, and cross-maps these with the requirements of a few main application domains. The results of this analysis should help in defining the technical characteristics needed to build efficient and effective 3D data presentation, taking into account the application contexts.

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Introduction

Three-dimensional (3D) data has evolved from being merely specialized content, used just by a small community of professionals, to a completely integrated web medium, now reaching a reasonable maturity level. Although the technological foundations needed to enable this new medium to bloom have been available for a few years, users' perceptions have changed only recently and 3D web content has now started to be able to reach the wider public. In this evolutionary process, a key role was played by the democratization of 3D content creation (the availability of low-cost 3D scanning devices, improvement of 3D-from-images/structure-from-motion approaches, the consolidation of manual modeling systems) and the introduction of a series of game-changing contributions addressed to a wider range of target users (3D printing applications, 3D viewer and editing systems embedded in common operating systems, etc.).

Nowadays, these new trends are pushing 3D content toward an unexplored world, where data management, user interactions, and cross-media integration are open issues still to be solved. Obviously the novel ecosystem we are envisioning is part of the web (a democratic space "par excellence"), and in recent years has been the subject of renewed attention concerning the integration of three-dimensional content and the development of resources specifically aimed at this.

However, despite the increased interest in recent years, the first attempts to bring 3D content online date back a long time. Indeed, web developers and 3D professionals understood very quickly the potential relevance of opening the web to 3D data, so that 3D should not stay trapped in standalone applications. A few months after the release of the first multimedia browser [able to manage just text and images; 163], Raggett [157] presented his vision for a platform-independent 3D standard for the web by proposing the Virtual Reality Modeling Language (VRML). The Web3D denomination emerged immediately after.

Unfortunately, such a prompt start was not followed by the same pace in the development of practical and consistent solutions, and the path toward an effective Web3D resulted in a long and winding process. Some major pioneering landmarks were the Macromedia Flash plug-in [44]—released in 1996, it was the direct ancestor of Adobe Flash and probably the first approach to handling fully interactive multimedia content online—and the Apple Webkit CANVAS [75], the first HTML drawing element controlled by means of JavaScript. Nevertheless, for a long time the web landscape has just been populated by a series of proprietary systems, third-party software, and closed solutions. Not having a common and recognized development standard was a strong limiting factor for the extensive publication and use of 3D content on the web.

The release of the WebGL application programming interface (API) [100] was a major breakthrough, starting the rapid growth of a new generation of applications, based on a common standard, that were able to act directly on the rendering pipeline and, above all, were supported by all common web browsers. In short, thanks to WebGL, Web3D entered in a new era. The first survey completely dedicated to web-based 3D graphics [57] demonstrated the mature status reached in this domain just four years after the introduction of WebGL.

Nowadays, the proposed Web3D approaches (considering both academic and commercial systems) are still very heterogeneous, since they adapt their data presentation strategy to the 3D content, the target users, the publishing venue typology, the application field, and the planned outcome. The growing number of solutions has contributed to familiarizing users with the presence of 3D on the web, but it has also resulted in an extremely complex scenario, where developers and users often find it difficult to orient themselves, especially those developers with a poor awareness of the particular needs of each specific combination of 3D data and application domain requirements.

This survey presents a review aimed at coping with these needs. Our main goal is to define a schema of the available possibilities and features supported by the enabling technologies and implemented systems. This is aimed at providing the reader with a map that, depending on the application field, could help in navigating through the technical characteristics needed to build an efficient and effective Web3D presentation. Our hope is that the result of this survey could be helpful for readers interested in mastering concepts that characterize the different phases of the 3D publishing process: content creators (enhancing their awareness about the Web3D ecosystem of libraries and authoring tools), content consumers (increasing their ability to fully experience the capabilities of existing systems), and finally also researchers and developers of future solutions.

For the purpose of this review we have evaluated a heterogeneous set of software applications and the state of the art of the scientific literature. The characterization of available solutions proved to be difficult, due to the heterogeneity of the approaches proposed and the number of issues to be considered. Moreover, this survey is designed to focus not only on the current trends, but also on the big challenges that researchers and developers face when sophisticated 3D graphics have to be efficiently ported to the web.

This monograph is organized as follows. Chapter 2 provides a short recap of the evolutionary process bringing us from the early Web3D phases up to the launch of WebGL. Chapter 3 presents three grand challenges to be faced in the development of 3D web content and resources. Chapter 4 presents the categorization adopted for the analysis of the state of the art of current Web3D solutions and technologies, defining a set of features required for 3D web publishing which are described in detail in

Chapter 5. Leveraging the previous results, Chapter 6 outlines the profile of the available publishing solutions and assesses the current solutions for a representative group of application fields. Finally, Chapter 7 presents the final considerations and future challenges.

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